Diffusion opportuniste d'alerte dans les scénarios de catastrophe

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Les communications opportunistes offrent une alternative intéressante dans les scénarios de catastrophes (e.g. tempête, inondation, et séisme) où l'infrastructure de communication peut être endommagée. Ce papier propose COPE, une solution coopérative de diffusion d'alerte, pour les scénarios de catastrophes, qui considère les différentes interfaces réseau intégrées dans les appareils mobiles. Afin de maintenir les appareils mobiles en vie le plus longtemps possible, les survivants forment des cliques et des zones dans lesquelles ils diffusent alternativement et périodiquement des messages d'alerte jusqu'à atteindre les potentiels sauveteurs à proximité. Les résultats de simulation montrent que COPE se révèle largement performant par rapport à la méthode de diffusion égoïste en terme de consommation d'énergie tout en garantissant un taux de délivrance d'alerte important.

Mots-clefs : diffusion d'alerte, communication opportuniste, consommation d'énergie, multi-technologies

1 Introduction

During disaster scenarios such as hurricanes, earthquakes and floods, communication is mostly needed for rescue operations of trapped survivors. However, network infrastructure might be damaged and thus no longer available. Opportunistic communication has been investigated as a promising solution to partially overcome this problem [NIK14]. Indeed, survivors trapped inside a disaster area can use their mobile devices (e.g. smartphones) and exploit opportunistic communication to diffuse emergency alert to reach proximity rescuers. However, alert diffusion in disaster scenario presents two main challenges. On the one hand, rescue operations may take long time, requiring mobile devices battery to be preserved as long as possible. On the other hand, mobile devices present multiple network interfaces (e.g. WiFi direct, WiFi adhoc, bluetooth) and the choice is usually left to the user who has no idea what is best or might be in a physical or psychological distress preventing him/her from making the best choice [DSB14]. Literature works consider mobile devices with only one network interface and most of them are based on a selfish-based alert diffusion which might quickly drain the device battery [RAT+15, MCCYM13].

The goal of this paper is thus to design an energy-efficient opportunistic alert diffusion scheme useful for trapped survivors during disaster scenario. This work presents COPE, a cooperative alert diffusion scheme, that exploits multiple network technologies integrated in mobile devices. COPE performance is evaluated through extensive simulations and results show that COPE significantly outperforms the selfish based diffusion in terms of energy consumption while guaranteeing an important alert delivery rate.

2 Cooperative Opportunistic Alert Diffusion

This work considers a set of nodes (i.e. survivors) $\mathcal{S} = \{s_i\}$, each equipped with a mobile device using multiple network interfaces $\mathcal{N} = \{n_i \mid i \in [1..N]\}$. These latter have different characteristics, mainly the energy consumption (*EC*) and the transmission range (*TR*). It is assumed that, for all $i \in [1..N-1]$ network interfaces, the n_{i+1}^{th} has larger transmission range (*TR*) and consumes more battery power (*EC*) than the network interface n_i as follows : $TR_{n_{i+1}} > TR_{n_i} \quad \& \quad EC_{n_{i+1}} < EC_{n_i}$

We stress that the system model can also be suitable with a mobile network composed of nodes having each a single communication interface that can be managed by different transmission powers (e.g. low, medium, high) leading consequently to different transmission ranges as well as different energy consumption. COPE dynamically copes with all kinds of devices and interfaces, making decision only on the characteristics of the link.

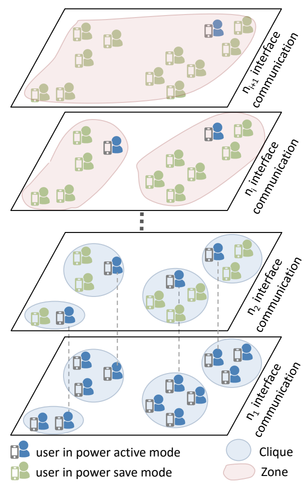

FIGURE 1: Layer-based communication overview

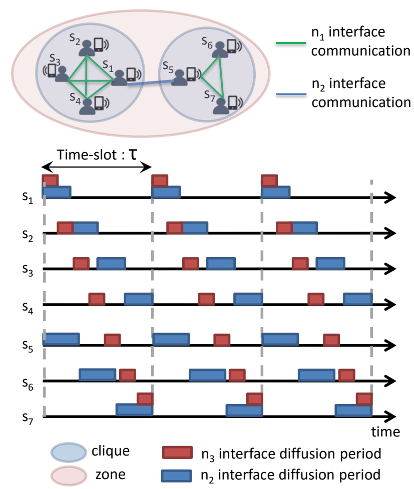

FIGURE 2: Alert diffusion illustration for two cliques forming a zone

This work proposes **COPE**, a **C**ooperative **OP**portunistic al**E**rt diffusion scheme for disaster scenarios. COPE aims to help survivors cope with disaster scenarios by diffusing alert messages. The alert message represents a short message that comprises mainly the node identifier (ID) and location information to ease the rescue operation. COPE is based on two main features. On the one hand, as survivors are usually trapped in groups during disaster scenarios and a selfish diffusion might quickly drain the battery, this work considers a cooperative-based diffusion to increase the battery power lifespan. On the other hand, COPE considers mobile devices equipped with multiple network technologies and performs a systematic interface selection since users usually do not know the best choice or they are physically or psychologically unable to make this choice.

This work is based on an interface layer-based communication scheme as shown in Fig. 1. Each layer presents the communication from the network interface n_i perspective. The time horizon is divided into time-slots τ. A time synchronization is required between nodes which is already done since mobile phones get the local time from the mobile network operator.

Nodes keep constantly the less-energy-consuming network interface n_1 on and use it to discover neighboring nodes and exchange their 1-hop neighbors. Hence, proximate nodes can form cliques. From the interface n_2 communication perspective, inside each clique, nodes cooperate, alternately, to discover proximity nodes and diffuse the emergency alert. Hence, at an instant of time, only one node enter in active mode and diffuse the alert message using the interface n_2 while other nodes inside the same clique enter in sleep mode. The wake-up period corresponds to the time-slot τ divided by the number of nodes inside the clique. The wake-up schedule of a node is determined in a distributed manner such as based on the node ID (e.g. node with the lowest ID start diffusing first). If a node belongs to more than one clique, it computes its diffusion period considering the clique having the minimum number of nodes.

If a node discovers other proximity nodes using the network interface n_2, these latter form a zone comprising the cliques that the nodes belong to. Afterwards, these nodes diffuse the zone information to the cliques they belong to, using interface n_1. Thereafter, nodes inside the same zone cooperate alternately for longer range diffusion using the network interface n_3. Following this concept, from the n_i^{th} communication perspective, nodes inside the same zone cooperate alternately to discover other proximate zones and/or to alert potential proximity rescuers. If ever a node discovers other nodes from another zone, they form a superior zone and inform other nodes belonging to the same clique/zone using the active interfaces. Then, a cooperation inside the new zone is performed based on the network interface n_{i+1}. When a survivor gets a response from a rescuer, it informs automatically rescuers about other proximity cliques/zones saved in its memory. Therefore, rescuers can make a fast intervention for other survivors in proximity. It assumed that the network topology is slowly time varying. Therefore, update messages are exchanged only when a node join or leave a clique/zone.

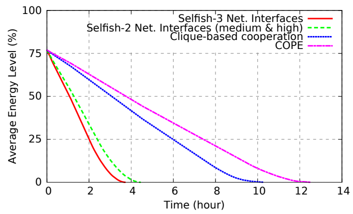

FIGURE 3: Average energy level over time

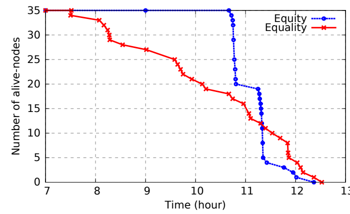

FIGURE 4: Number of alive-nodes over time

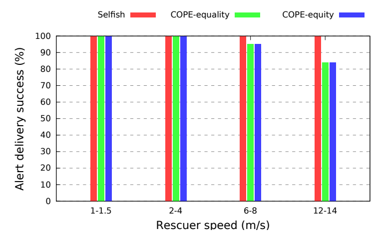

FIGURE 5: Emergency alert delivery success (all nodes are alive)

Motivating scenario : Fig. 2 illustrates an example of a simple scenario considering 7 nodes equipped each with a mobile device having 3 network interfaces. The scenario considers survivors trapped in two proximate locations and can form two cliques $C_A = \{s_1, s_2, s_3, s_4\}$ and $C_B = \{s_5, s_6, s_7\}$ based on the interface n_1. Inside clique C_A (C_B respectively), using the network interface n_2, nodes cooperate alternately to diffuse the alert message during a wake-up period of $\tau/4$ ($\tau/3$ respectively). Since nodes s_1 and s_5 communicate using the interface n_2, they form a zone comprising cliques C_A and C_B and they diffuse the zone information to the nodes inside the same clique using the interface n_1. Similarly, based on the network interface n_3, nodes inside the formed zone cooperate alternately during a wake-up period of $\tau/7$ each.

This simple scenario shows the considerable energy that nodes can save comparing to the selfish-based diffusion. Indeed, nodes belonging to cliques C_A and C_B can save approximately 75% and 66% of battery power respectively, with respect to the n_2 based communication. Similarly, they can save about 85% of battery consumption with respect to the n_3 based communication.

3 Performance Evaluation

COPE performances have been evaluated by simulations conducted through the Opportunistic Network Environment (ONE) [KOK09]. Simulations involve 35 mobile nodes (survivors). The mobility generator of BonnMotion has been used to generate mobility traces of users in disaster scenario [AEGPS10]. The BonnMotion disaster mobility model generates movement driven by tactical reasons based on a method called separation of the rooms. Using this method, the disaster scenario is divided into different context-based areas which are : incident site, casualty treatment area, transport zone, and technical operational command zone. We stress that survivors are considered with low mobility inside limited locations such as a parking place or a building. Thus, the network topology is considered slowly time varying. Each user is considered equipped with a mobile device having 3 network interfaces corresponding to low, medium and high transmission range and to low, medium and high battery power consumption. For the sake of simplicity, the energy level is expressed as a percentage of the battery capacity (i.e. 100% : mobile device battery is fully charged ; 0% : mobile device battery is empty). In the beginning of the simulation, each node gets an initial random energy level comprised in the range of $[50\%, 100\%]$.

COPE is compared with selfish and clique-based cooperative alert diffusion schemes. The former considers that each survivor only counts on himself for his survival. The survival can either use many network technology of his mobile devices or he can use the most useful ones. The latter consists of cooperative diffusion limited to the nodes inside a clique formed by proximity nodes (without zone formation).

3.1. Cooperative vs Selfish Alert diffusion

Figure 3 shows the average power consumption considering the selfish and cooperative based alert diffusion schemes. Selfish based diffusion methods drain rapidly the batteries. Indeed, considering 2 and 3 network interfaces, the battery drain after approximately 3h30 and 4hours, respectively. Differently, cooperative-based alert diffusion schemes increase significantly the battery lifetime. Indeed, the battery hold up to approximately 10 and 12 hours considering COPE and clique-based diffusion, respectively.

3.2. Various initial energy levels

Considering different initial energy levels, COPE is evaluated under two different strategies : *equality-based* and *equity-based*. The former is based on an alert diffusion for equal period of time within the same clique/zone. The latter consists of alert diffusion where nodes with higher energy level diffuse the alert message for longer period of time comparing to those with low energy level until making a balance between nodes inside the same clique/zone.

Fig. 4 presents the number of alive nodes (i.e. still have power in their batteries) over time for both equity-based and equality-based alert diffusion methods. On the one hand, since nodes have initially various energy levels (difference up to 50%), equality-based method allows the nodes with high energy to live for a long time (approximately 12.5 hours) while other nodes with low energy can live for much less time (approximately 8 hours). On the other hand, considering equity-based method, nodes with low energy can live longer (more than 10.5 hours). Obviously, nodes with high energy could live less time comparing to equality-based method since they will spend more energy due to the longer diffusion period. In spite of that, these nodes wasted only few minutes ($\sim$ 30 min) which could maintain many other nodes in the network to stay alive longer (more hours) and consequently to maintain the whole network connected for longer time.

3.3. Alert message delivery efficiency

Previous results have shown the efficiency of COPE with respect to the battery power. In the following, COPE performance is evaluated in terms of alert message delivery success. Simulations were conducted and consider 100 different scenarios where a rescue-node moves with random path around and inside the disaster area. We count the successful emergency alert that could be delivered to the rescuer-node considering COPE-equity, COPE-equality and selfish (using 3 interfaces) diffusion methods. For a fair comparison, we consider a scenario in which all nodes are alive (the period $[0, 2h]$ on Fig. 3).

Fig. 5 shows that the different diffusion methods succeed to deliver the alert message to the rescuer (100%) for a walk and running speed (1-1.5m/s and 2-4 m/s). When the rescuer speed increases (6-8m/s and 12-14m/s), Selfish diffusion can always deliver the emergency alert while COPE shows a slow decrease since rescuer-node can enter and leave the coverage of a sleep-node before its wake-up. This case is not very realistic since in real environment rescuer-nodes will move slowly to carefully search for any survivor. Even though, COPE can be adapted by reducing the time-slot duration allowing nodes to switch quickly between the sleep and active modes and can thus reach rescuer with high mobility.

4 Conclusion

This paper investigates the alert diffusion in disaster scenarios. A novel cooperative alert diffusion scheme, named COPE, was proposed. Unlike existing works, COPE considers and exploits multiple network technologies integrated in mobile devices. COPE allows to preserve the battery power for longer time and guarantee a high alert delivery success. The performance of COPE is emphasized through simulation studies and results show its efficiency comparing to selfish alert diffusion.

Acknowledgment

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Références

[AEGPS10] N. Aschenbruck, R. Ernst, E. Gerhards-Padilla, and M. Schwamborn. Bonnmotion : a mobility scenario generation and analysis tool. In *SIMUTools*, page 51, 2010.

[DSB14] Shuo Deng, Anirudh Sivaraman, and Hari Balakrishnan. All your network are belong to us : A transport framework for mobile network selection. In *HotMobile*, page 19. ACM, 2014.

[KOK09] Ari Keränen, Jörg Ott, and Teemu Kärkkäinen. The ONE Simulator for DTN Protocol Evaluation. *SIMUTools*, page 55, 2009.

[MCCYM13] A. Martín-Campillo, J. Crowcroft, E. Yoneki, and R. Martí. Evaluating opportunistic networks in disaster scenarios. *J. Network and Computer Applications*, 36(2) :870–880, 2013.

[NIK14] Hiroki Nishiyama, Masaya Ito, and Nei Kato. Relay-by-smartphone : realizing multihop device-to-device communications. *IEEE Communications Magazine*, 52(4) :56–65, 2014.

[RAT+15] DG Reina, M Askalani, SL Toral, F Barrero, E Asimakopoulou, and N Bessis. A survey on multihop ad hoc networks for disaster response scenarios. *International Journal of Distributed Sensor Networks*, 2015 :3, 2015.